

HOUSING PRICES AND SUBMARKETS IN MEXICO CITY: A HEDONIC ASSESSMENT*

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Resumen: El objetivo del artículo consiste en explorar variables cuantitativas que permitan explicar los precios de la vivienda en la Ciudad de México y la manera en que dichas variables pueden ser utilizadas para la delimitación de submercados de vivienda. La estrategia metodológica consiste en utilizar elementos de la teoría económica espacial, el diseño y aplicación de un modelo econométrico de precios hedónicos para analizar las principales características de la demanda habitacional y un modelo de análisis de conglomerados de dos pasos o bietápico, para explorar los submercados de vivienda. Los modelos utilizan información de los microdatos de la *Encuesta nacional de ingreso y gasto de los hogares 2010*.

Abstract: The objective of this paper is to explore the role of some quantitative variables in explaining housing prices, and how these variables can be used for the spatial delimitation of housing submarkets. The methodological strategy incorporates issues from the spatial economic theory, and an econometric model of hedonic prices to analyze the main characteristics of housing demand in Mexico City. Housing submarkets are delimited by using a statistical multivariate tool, two-step, log likelihood cluster analysis, in terms of intra-urban relative house differentials. The models are estimated using cross-sectional data from the 2010 micro-data of Mexico's National Survey of the Households' Incomes and Expenditures.

Clasificación JEL/JEL Classification: R14, R21, R23, R31

Palabras clave/keywords: Ciudad de México; mercado urbano de vivienda; unidades de vivienda; submercados de vivienda; modelos hedónicos de precios de la vivienda, Mexico City, urban housing market, housing units, housing submarkets, hedonic models of housing prices

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1. Introduction

The Mexico City Metropolitan Area (MCMA) was the third largest urban agglomeration in the world in 2010, behind Tokyo and Delhi (United Nations, 2012). MCMA is constituted by the 16 boroughs of the Federal District, 59 municipalities of the state of Mexico, and one municipality of Hidalgo, with a population of 20.1 million people. (SEDESOL, CONAPO and INEGI, 2012). Population growth in this metropolitan area has been lower, since 1980, compared to that of the country; for instance, between 2000 and 2010 the latter grew at an annual average of 1.4% and the former at 0.9%. For this reason, the share of the metropolis in the national population has fallen from 21.6% in 1980 to 17.9% in 2010.

Recent housing studies in the MCMA have addressed four great issues: *i*) social division of the space; *ii*) urban land use; *iii*) housing production processes; and *iv*) housing policy. Social division of the space consists of the broad outlines of the social organization of the city (Rubalcava and Schteingart, 2012), meanwhile segregation refers to the unequal distribution of the population in the urban area according to demographic, economic or social attributes (Latham, *et al.*, 2009). Social division of the metropolitan space has been studied through two different statistical tools; the first is multivariate analysis, mainly factor analysis and principal components, using boroughs and municipalities (Aguilar and Alvarado, 2004; Duahu, 2003; Monkkonen, 2012), census tract –basic geostatistical area (Monkkonen, 2011; Rubalcava and Schteingart, 2012), or blocks (Aguilar and Mateos, 2012) as observation units. The second tool is univariate analysis, by building segregation and dissimilarity indexes (Sánchez, 2012). The main findings of this literature have been as follows: *i*) a confirmation of urban consolidation patterns between 1950 and 1980, and the lower intensity of this consolidation since 1990; *ii*) an improvement in material conditions of dwellings, and its relationship with household income; *iii*) a slower rate of change in the spatial differentiation with respect to demographic, economic or social change; *iv*) more residential segregation due to high-income households, and *v*) an increase in the residential segregation index between middle and lower-income households.

Research on urban land have emphasized the contemporary metropolitan urbanization, especially following the changes in 1992, to Article 27 of the Mexico's federal constitution, which opened up communal and ejido land for urban development (Duhau and Cruz, 2006; Ugalde, 2012). However, these changes have not altered former patterns, so that irregular settlements remain as the primary form in the

MCMA's urbanization. According to Connolly (2012), between 1990 and 2005 the metropolitan surface grew in 27 121 hectares, and 36% of this growth occurred in ejido land. Furthermore, this reform resulted in delays and complications in the regularization of land ownership in consolidated settlements (Salazar, 2012).

Another topic is that of land reserves for urban growth. Mexico does not have a national public policy on land reserves, so private urban developers and real estate agencies are been responsible for acquiring and managing land for urban growth (Coulomb and Scheingart, 2006). These private agents acquire either private or ejido land, as an asset for future developments (Castro *et al.*, 2006). In the case of the Federal District, Lopez Obrador's administration implemented a policy, known as *Bando 2*, oriented to encourage redevelopment of land in the center of the city, and to inhibit peripheral expansion (Azuara, González and Tamayo, 2007). However, even though the central city depopulation stopped, peripheral boroughs (such as Cuajimalpa, Milpa Alta and Tláhuac) continued their urban expansion.

Housing production processes in urban Mexico have been carried out through three major mechanisms: *i*) self-construction; *ii*) custom housing, and *iii*) mass production. Self-construction is the main mechanism for increasing the number of dwellings that are gradually built, often on ejido land, and without the intervention of a formal credit mechanism (Connolly, 2006). Mass production of housing has been carried out by private companies, and by the public sector through the national housing agencies, until 1993, when the latter were reoriented towards the facilitating and financing the acquisition of housing (Patiño, 2006; Puebla, 2006). In other words, they changed from being agencies that support housing supply, to agents that promote housing demand.

For this reason, private companies became the key actors in formal housing production, making residential developments of thousands of dwellings in peripheral land, often without building the necessary infrastructure and equipment (Castro *et al.*, 2006). They have built housing, but they have not built cities; thus promoting imbalances between urban growth and urban planning.

Housing policy includes not only the performance of housing national agencies, but also some actions related to urban planning, regulations for urban growth, public administration structures, and relationships among social actors. Housing policy has had a differential impact across the metropolitan area, forming a scattered pattern of daily mobility (Isunza, 2010). In the Federal District, the election of the head of the government was first introduced in 1997, and it was

supposed to open the opportunity to change the policy making process for the city; however, housing policy has remained the same and there have been no benefits for any social group (Contreras, 2012).

The amount of academic publications on these issues contrasts with the absence of studies on urban land and housing prices. This is mainly due to the lack of information on prices. One traditional source of data has been the notes and newspaper ads, which suffer from huge problems in accreditation and longitudinal comparison (see Guadarrama, 2007). Another source is *Sociedad Hipotecaria Federal* (Federal Mortgage Company, or SHF for its initials in Spanish), a public agency created in 2002 to promote the development of primary and secondary markets for mortgage lending. It has some useful housing statistics, such as annual average market value of homes by zip code, or annual average market value per square meter of construction by zip code (SHF, 2013a).

In view of this gap in the literature about housing markets in Mexico, the aim of this paper is to explore the role of a number of variables highlighted by the spatial economics theory in explaining housing prices in Mexico City, and how these variables can be used for a spatial delimitation of housing submarkets. In order to achieve these goals, the paper is developed as follows. The second section presents a brief literature review of the main characteristics of the urban housing market, and how the submarkets are defined. The third section describes the data and the empirical model. The fourth section presents the empirical results and discusses the findings. The last section contains some final remarks.

2. Drivers of division in the housing market

Housing, as a commodity, contains the following specificities (Mills and Hamilton, 1994; O'Sullivan, 1996): *i*) heterogeneity in relation to quantity and quality supplied and demanded; *ii*) this heterogeneity means that the urban housing market can be disaggregated in different spatial submarkets, according to housing characteristics and accessibility patterns; *iii*) immobility; *iv*) durable; *v*) high price; *vi*) the cost of moving is high; *vii*) housing location has implications derived from the neighborhood in terms of positive and negative externalities; and *viii*) its production is related to the city's economic growth.

In spatial economic theory, two main analytical perspectives, which are closely interrelated, are used to study the urban housing market. The first and earliest perspective is related to models of residential location, where the factors that intervene in the family choice

for selecting a house are emphasized (Goodall, 1972; O'Sullivan, 1996; Papageorgiou and Pines, 1999; Richardson, 1986). The family's residential objectives are direct (accessing to a space for living), and indirect (related to the location of the dwelling and the amenities of the neighborhood). The factors of the residential selection are: *i*) family income and the income-elasticity of demand; *ii*) place of work, which has to do with transport costs; *iii*) family composition, in terms of size and ages; *iv*) characteristics of the house, that is quantity and quality; and *v*) characteristics and amenities of the neighborhood, or externalities. The premise for residential selection is that it is restricted to the spatial distribution of the existent supply, with a limited supply of new housing and a higher supply of used housing.

Precursor models of residential location were elaborated by Wingo (1963) and by Alonso (1964), whose contributions were incorporated later, making adjustments to the initial premise and the explanatory variables of analysis. The Wingo and Alonso models began with the argument of a monocentric city, a market for land characterized by perfect competition, and a homogeneous good, housing. Families, according to their income, maximize their housing utility when comparing the costs of acquisition and the costs related to transport; each one selects the desired combination of land-transport costs. This trade-off framework between land costs and transport costs is called compensatory model. In compensatory models, the social division of the city develops according to differences in income among families, and the choice they make between living near the workplace (located in the Central Business District or CBD), or in a larger house (located far away from the CBD). Therefore these models assume that housing is homogeneous in quality and neighborhood externalities, but different in terms of size and location.

The second perspective aims at determining the variables that explain the supply and demand in the housing urban market, with the first assumption that housing is not only heterogeneous in terms of size and location, but also in relation to quality and neighborhood attributes (Balchin, Isaac and Chen, 2000; Hirsch, 1977; Papageorgiou and Pines, 1999). From the supply point of view, the agents that intervene in the housing production are: *i*) developers; *ii*) builders; *iii*) sellers; *iv*) public agencies; and *v*) companies and agents related to repair and maintenance. Moreover housing supply can be divided into private, public or mixed, according to the agents involved, and into formal or self-constructed, according to the market.

In the short term, housing supply, or housing stock, is relatively fixed and changes in price have no impacts in the quantity supplied. In

the long term, the supply is the result of: *i*) the price of new housing, housing with low damage and renovated housing; *ii*) the availability of land; *iii*) the input costs; *iv*) the cost of loans to acquire land and other related inputs; *v*) the provision of infrastructure and services, and *vi*) policy and regulatory provisions for housing production.

Demand has to be analyzed first on the consumption side (rent or buy), and then its determinants in the short and long term must be analyzed. In the short term, demand controls the aggregate housing market and depends on: *i*) family income; *ii*) future expectancy of income; and *iii*) access to finance provided by commercial and mortgage banks, or state resources. In the long term, demand depends on: *i*) housing prices; *ii*) family incomes; *iii*) population size; *iv*) age pyramid; *v*) family arrangements, and *vi*) subsidies that reduce rates and housing prices.

The specificities of this good and the attributes of supply and demand produce a particular price elasticity for this good. The price elasticity of demand consists of the percentage change in housing consumption when price changes, with a constant family income. According to O'Sullivan (1996), this relationship is negative and inelastic (around -0.85), that is, consumption decreases when the price is higher but the variation is less than proportional. Thus, family expenses for housing consumption are relatively higher when prices increase. On the other hand, the income elasticity of demand refers to a percentage change in housing consumption before a change in income, with a constant price. Housing behaves as a normal good (0.75 approximately) but with larger variations according the income level of families; those with less income have an income elasticity of demand between 0.1 and 0.6, while those with higher income have elasticity between 0.7 and 1.1. When the elasticity is higher than one, then the good in question is a superior good.

The different kinds of possible imbalances in the housing market can be summarized as follows: *i*) static, in terms of the number of houses (supply), and in relation to the number of families (demand); *ii*) dynamic, that is, showing a change in the number of houses in relation to the change in the number of families; *iii*) spatial, from the supply-demand point of view in a city or an area into the city; and *iv*) qualitative, in terms of the supply and demand quality. These imbalances can include two antagonistic events occurring in the city at the same time: *i*) housing glut (vacant or abandoned), and *ii*) housing shortage (for families without housing, deteriorating housing stock or overcrowding). These antagonistic events are complemented by two processes resulting from the spatial form of the market: *i*)

residential segregation, or spatial separation of families with similar characteristics, and *ii*) gentrification, or socio-spatial change upward or downward that occurs as a result of residential mobility.

For all these reasons, the urban housing market cannot be seen and analyzed as a single market, but as compartmentalized geographical submarkets. The housing submarket has been defined in two different forms: *i*) as a cluster of dwellings which could represent close substitutes to each other, independently of where they are located, and where substitutability means demand is relatively indifferent between the entire bundle of physical (size and quality), location and neighborhood attributes characterizing the competing housing units (Grigsby, 1963), and *ii*) as a cluster of dwellings with homogeneous prices, and price differentials with respect to others submarkets, where the housing price is analyzed through a hedonic approach according to a standardized dwelling (Jones, Leishman and Watkins, 2004).

The study of urban housing submarkets provides the following information: *i*) the operation of housing markets; *ii*) the impact of property taxes; *iii*) the estimation of price indices; *iv*) the effect of urban policies; and *v*) the relationship between intra-urban residential mobility and submarkets. According to Leishman (2009), housing submarkets exist if there are significant differences in estimates from hedonic housing price models. The most commonly-employed method to define housing submarkets is to begin with some prior notion of where submarkets are likely to exist. The standard statistical test uses a three-step procedure: *i*) hedonic housing price functions are estimated for each a priori submarket; *ii*) a Chow test is compute to establish if there are significant differences among the estimates of each function; and *iii*) a weighted standard error is calculated for the submarket model, to test the significance of price differences for standard dwellings across submarkets (Watkins, 2001).

Other methods for analyzing some prior notion of housing submarkets are the iterative process and the use of the residuals. In the iterative process, the stability of the coefficient of an interaction effect is used to determine whether or not successive spatial units should be aggregated to a defined submarket (Goodman and Thibodeau, 1998). The second approach uses the residuals resulting from a hedonic estimation for the purpose of assessing spatial patterns and submarkets; the method consists on measuring spatial autocorrelation in order to calculate a non-random spatial pattern (Basu and Thibodeau, 1998). Undefined submarkets can be studied with a neural network approach (Kauko, 2004), by clustering spatial units according to variables in-

volved in housing prices (Tu, Sun and Yu, 2007), or with spatial autocorrelation (Wong, Yiu and Chau, 2013).

The spatial distribution of families according to income levels in Latin American cities is different in relation to those observed in cities from developed countries (Rubalcava and Scheingart, 2012). In Latin America, families with higher income decide, in general, to locate in more central places, where they have better infrastructure and services; while families with fewer resources are located in the city's periphery, which is characterized by less-desirable conditions of habitability and accessibility. Physical expansion in Latin American cities has been characterized by the formation and expansion of irregular settlements, which have allowed the work force to grow at a low cost. This type of urbanization began in the 1940s and has represented a certain level of improvement in living conditions for poor migrants from the most backward rural areas that arrived at cities, although this increased in wellbeing is more symbolic than real.

In summary, there are three main groups of variables that explain residential choice: *i*) dwelling characteristics (quantity and quality); *ii*) characteristics of the neighborhood (externalities and public services); and *iii*) accessibility (to workplaces, to retail centers, to the rest of the city). The housing market is a mix of different geographical submarkets, which are expressed in the spatial social division; they can be defined and delimited in terms of house prices, and they will exist where the price of a standardized dwelling, or the household income, in one zone differs from other parts of the city.

3. Data and research methodology

In any city, housing is different in size, quality, externalities and location. This paper tries to explain how these differences are expressed in the MCMA's housing market. We start with the classical utility function, in which the household maximizes its utility in the consumption of housing:

$$U = U(X, H, C)$$

where X : units of all non-housing goods; H : units of housing services (size, quality, and externalities, or neighborhood attributes), and C : commuting time (accessibility). This utility function is constrained by the income:

$$X + H + wC = wW + V$$

where w is the wage rate, W is the hours at work, and V is the additional non-labor income; wC is the commuting cost to the workplace. Following Levernier and Cushing (1994), McDonald (1979:169-185), O'Sullivan (1996:365-408), and Straszheim (1975:142-165), these single relations can be transformed into an econometric model to study the urban housing market, by using a hedonic price approach. The hedonic approach is based on the notion that a dwelling is composed of a bundle of individual components (physical, externalities, and accessibility), each of them having an implicit price. This model assumes that housing stock availability, neighborhood attributes, and employment access are exogenous; while income and housing prices are endogenous:

$$\Sigma_j wF = f(H, N, C)$$

where $\Sigma_j wF$ is the total household income (the sum of the j members inserted in the labor market), H is a matrix describing the physical characteristics of the dwelling (size, quality, age, and tenure); N is a matrix describing the neighborhood attributes (public services, retail facilities, school quality, air pollution, segregation index), and C is a matrix describing accessibility to work (distance of each j household member to their workplace).

The standard or classic hedonic model is as follows:

$$P_i = \alpha + \Sigma \beta_k X_{ki} + v_i$$

where P_i is the price of the i th dwelling, and X_{ki} represents a vector of physical, neighborhood and accessibility housing attributes. This will be the restricted model in the test for structural differences among urban submarkets. Meanwhile the unrestricted hedonic model will result from the following function:

$$P_{ij} = \alpha + \Sigma \beta_{ki} X_{kij} + (v_i + \varepsilon_{ij})$$

where P_{ij} is the price of the i th dwelling in the j th submarket, and X_{kij} represents a vector of physical, neighborhood and accessibility housing attributes in the j th submarket. The empirical sections of this paper are based on the following steps:

- An ordinary least squares hedonic estimation is carried out for housing prices, assuming a unitary housing market, and using explanatory variables related to size and quality of the dwellings, neighborhood attributes and accessibility indicators. This model is applied to owner-occupied houses and to houses for rent for all the dwellings.
- The MCMA spatial units –boroughs and municipalities– are clustered by using a two-step, log-likelihood cluster analysis. The algorithm makes use of the variables explaining housing prices. The definition and delimitation of submarkets are checked with the standard statistical tests (Chow and weighted standard error tests).
- Factor analysis is undertaken to reduce the variables explaining housing prices into a single factor value, called housing unit. This value is then regressed on household income and on housing price in order to get income and price elasticities.
- An origin-destination matrix is built to explore residential mobility in terms of intra-submarket and inter-submarkets flows.

Empirical work draws on data from the new version of the 2010 National Survey of Household’s Incomes and Expenditures (*Encuesta nacional de ingresos y gastos de los hogares*, ENIGH), elaborated for the National Institute of Statistics and Geography (*Instituto Nacional de Estadística y Geografía*, INEGI). This dataset includes a sample of the total national housing, families and individuals. The sample size for MCMA was big enough for its statistical significance (INEGI, 2012). Missing observations were eliminated and the final dataset includes 4 402 dwellings, which multiplied by the expansion factor, are equal to 4 575 449 dwellings. They are located in 57 of the 76 spatial units that make up the metropolitan area. All the statistical exercises were done with SPSS. Table 1 shows the descriptive statistics of the variables for the hedonic models.

Explanatory variables were grouped according to the three key attributes determining housing price: *i*) dwelling characteristics; *ii*) neighborhood attributes; and *iii*) accessibility. Dwelling characteristics included two variables related to size, and five allied to quality. House size was evaluated by the number of *bedrooms* and the number of *lights*, while housing quality included three dummy variables (brick, cement or stone *walls*; presence of a *kitchen*; and presence of a *water cistern*); and a variable for *age*, and a dummy indicating if it was an independent *house*.

Neighborhood attributes were represented by five variables: three of them were dummies, and the other two were built using data for other sources apart from the National Survey. The three dummy variables were if the house had indoor running *water*; if it had *sewage*, and if the *garbage* was collected by the local public service. The variable *educa* estimated the quality of the primary schools in the borough or municipality where the dwelling was located and used data from the National Test for the Education Quality, or *Enlace* test (SEP, 2012). The other predictor variable, *housing growth* quantified the rate of growth in housing stock, using data of boroughs and municipalities from the 2000 and 2010 national census of population and housing.

Finally, three variables were linked to accessibility: *dist_cbd* indicates the lineal distance to the CBD, and it was calculated from the geographic center of the borough or municipality to the *Zócalo*, commonly known as the heart of the metropolis. The second variable was *dist_hosp*, which was the lineal distance to the nearest hospital. The third was *lntransport*, or the natural logarithm of transportation cost.

These variables were used to predict housing price, measured in natural logarithm (*lnprice*), so the interpretation of the regression coefficients is as follows (Wooldridge, 2006): *i*) for the quantitative explanatory variables (*bedrooms*, *lights*, *built*, *educa*, *housing_growth*, *dist_cbd*, and *dist_hosp*), the coefficients show the percentage change of *lnprice* due to a change in one unit in the variable, given the same amount of the remained control variables ($\% \Delta y = (100\beta)\Delta x$); *ii*) for the logarithm variable (*ln_transport*), the coefficient estimates the percentage change of *lnprice* because of a one percent increase in this variable, given the same amount of the remained control variables ($\% \Delta y = \beta\% \Delta x$), and *iii*) in the case of the dummy variables (*house*, *walls*, *kitchen*, *cistern*, *water*, *sewage* and *garbage*), the coefficients estimate the percentage change in *lnprice* between a house with this item and those without that, holding the other independent variables constant ($\% \Delta y = 100\beta$ if $x = 1$).

4. OLS hedonic model results

The demand for housing depends mainly on household income and price of housing. In 2010, the average quarterly household income in MCMA was 47 439 Mexican pesos, with a standard deviation of 58 608. The average quarterly housing rent was 8 954 Mexican pesos, and its

standard deviation was 10 806.¹ This means that the average share of expenditure in housing was 19 per cent. The correlation between household income and housing price was 0.696, significant at the 0.01 level. The elasticity was 0.720, which means that a 10% increase in income produces a 7.2% increase in housing expenditure.²

Table 1
Descriptive statistics of the variables

<i>Variable</i>	<i>Definition</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Minimum</i>	<i>Maximum</i>
<i>submarket</i>	Social stratification area according to Rubalcava and Scheingart, 2012	3.15	1.26	1	6
<i>price</i>	Quarterly rent paid for the tenure, or that would be paid for the owner to live in this house, in Mexican pesos	8 954	10 806	302	151 233
<i>lnprice</i>	Natural log of price	8.73	0.81	5.71	11.93
<i>income</i>	Quarterly household income, in Mexican pesos	47 439	58 608	726	952 585
<i>lnincome</i>	Natural Log of income	10.41	0.79	6.59	13.77
<i>transport</i>	Household quarterly cost on transportation, in Mexican pesos	5 507	8 088	36	312 946
<i>factor_score</i>	Dwelling component score from the factor analysis	0.00	1.00	-4.16	2.66
<i>home_index</i>	New scale of the dwelling component score, where the minimum = 1	5.16	1.00	1.00	7.82
<i>Dwelling characteristics</i>					
<i>house</i>	D = 1 if the dwelling is an independent house	0.69	0.46	0	1
<i>bedrooms</i>	Number of bedrooms	2.03	1.04	1	22

¹ The exchange rate in 2010 was 12.64 Mexican pesos per US dollar. So, the average quarterly household income was 3,753 dollars, and the average quarterly housing rent was 708 dollars.

² This elasticity was calculated by using a simple OLS model, having *ln_price* as regressand, and *ln_income* as regressor. This is different compared to demand income elasticity and demand price elasticity, which are discussed later.

Table 1
(continued)

<i>Variable</i>	<i>Definition</i>	<i>Mean</i>	<i>Std. Devi- ation</i>	<i>Min- imum</i>	<i>Max- imum</i>
<i>walls</i>	D = 1 if the walls are of brick, cement or stone	0.96	0.18	0	1
<i>kitchen</i>	D = 1 if there is a kitchen	0.94	0.23	0	1
<i>cistern</i>	D = 1 if there is a water cistern	0.50	0.50	0	1
<i>lights</i>	Number of lights	7.59	6.24	0	70
<i>built</i>	Dwelling age	24.40	14.18	0	99
<i>Neighborhood attributes</i>					
<i>water</i>	D = 1 if there is inside running water	0.79	0.41	0	1
<i>sewage</i>	D = 1 if there is sewage	0.94	0.25	0	1
<i>garbage</i>	D = 1 if the garbage is collected by the local public service	0.95	0.21	0	1
<i>educa</i>	Average rate of the municipality's primary schools in the performance at the National Test for the Education Quality (<i>Enlace</i>)	565	18	511	616
<i>housing_growth</i>	Housing rate of growth in the municipality between 2000 and 2010	1.87	1.77	-0.25	12.73
<i>Accesibility</i>					
<i>dist_cbd</i>	Lineal distance from the municipality centroid to "Zocalo", in kilometers	15.88	11.03	1.00	60.98
<i>dist_hsop</i>	Lineal distance to the last visited hospital by the respondents	0.77	1.80	0.03	45.00
<i>lntransport</i>	Natural log of the quarterly expenditure in transport	8.13	1.02	3.59	12.65

Source: prepared by the author by using data from INEGI (2012).

An ordinary least squares hedonic estimation was carried out in order to know the elements behind housing prices in MCMA (table 2). Five models are shown: *i*) for housing; *ii*) for owner-occupied

houses, *iii*) for dwellings for rent; *iv*) for other kind of tenure; and *v*) for own house interaction.³ A first conclusion is that there is a high level of significance for all the estimates. Such a result could be caused by multicollinearity. The effect of multicollinearity means that the standard error of β tends to rise, but it does not bias coefficient estimates. A variance inflation factor (VIF) statistics was calculated in order to analyze multicollinearity. A larger VIF produces bigger variance on regression coefficients, making estimates unstable. However, the results showed no problems with multicollinearity, because there were only two variables with signs of collinearity (*dist_cbd* and *housing_growth*). These variables got a VIF value over 2.5, but they were kept in the models due to their theoretical impact on housing prices.

Table 2
OLS hedonic estimates for housing price in Mexico City, 2010

Variable	Models				
	1 <i>Total</i>	2 <i>Own</i>	3 <i>Rent</i>	4 <i>Other</i>	5 <i>Own interaction</i>
<i>intercept</i>	1.586	1.569	1.723	2.812	2.092
<i>house</i>	0.017	-0.003	-0.112	0.023	0.030
<i>bedrooms</i>	0.061	0.036	0.026	0.101	-0.012
<i>walls</i>	0.088	0.097	0.107	0.061	0.046
<i>kitchen</i>	0.288	0.277	0.221	0.185	0.054
<i>cistern</i>	0.122	0.140	0.129	0.047	0.059
<i>lights</i>	0.051	0.045	0.066	0.062	-0.023
<i>built</i>	0.003	0.003	-0.002	0.002	0.003
<i>water</i>	0.259	0.182	0.286	0.230	-0.079
<i>sewage</i>	0.061	0.113	0.027	0.110	0.030

³ The interaction term is an independent variable in a regression model that is the product of two explanatory variables, in this case own variable multiplied by each independent variable used in the model.

Table 2
(continued)

Variable	Models				
	1	2	3	4	5
	Total	Own	Rent	Other	Own interaction
<i>garbage</i>	-0.207	-0.094	-0.324	-0.309	0.261
<i>educa</i>	0.009	0.010	0.009	0.008	0.001
<i>housing—growth</i>	0.009	0.002	0.044	0.009	-0.011
<i>dist—cbd</i>	-0.008	-0.009	-0.017	-0.007	-0.001
<i>dist—hosp</i>	-0.005	-0.017	-0.002	-0.004	-0.015
<i>intransport</i>	0.109	0.103	0.181	0.072	-0.013
<i>N</i>	4 402	2 637	894	871	4 402
<i>N expanded</i>	4 575 449	2 689 170	956 292	929 987	4 575 449
<i>R-squared</i>	0.575	0.547	0.671	0.516	0.592
<i>Median price</i>	6 016	7 520	4 537	4 537	6 016
<i>Median income</i>	31 283	36 740	24 298	24 197	31 283

Note: all coefficients were statistical significant at 0.001 level.

Source: prepared by the author by using data from INEGI (2012).

Model 1 is the hedonic estimate of the housing prices in the whole MCMA in 2010. In general, the coefficients showed the expected relationship, except the coefficients for *garbage* and *dist_cbd*, which had negative signs. This means that housing prices were inversely related to garbage collected by local public service, and that housing prices decreased as their distance from downtown increased (an inverse relationship in comparison with US cities).

All the variables related to size and quality of dwellings present positive coefficients. The most sensitive coefficients correspond to *kitchen* and *cistern*; the average price of a dwelling increased around 29% when it had a special room for cooking, holding other factors fixed, meanwhile a house with cistern for running water was 12% more expensive on average that one without it. It seems that quality was more important than size in determining housing prices, because one

additional bedroom or one additional light implied only an increase of between 5 and 6% in the housing price. The coefficient related to the age of the house (*built*), was positive, indicating that the newest constructions may have been oriented more towards medium and low social strata, in the same way as these social groups increased their share in the total metropolitan population and stock housing between 2000 and 2010; however, the value of the coefficient was actually low, showing that an additional year in the housing age increased the price by only 0.3 per cent.

With respect to the variables measuring neighborhood attributes, the signs in their coefficients were as expected. For example, a house with inside running water was 26% more expensive than one without this service, holding all the other factors fixed. The only variable in this category that did not have the expected coefficient was garbage, as mentioned above. In this case, the lack of provision of this public service caused a 21% increase in the average price of the dwelling.

In the case of the variables related to location or accessibility, the model confirmed the negative relationship between housing price and distance to the CBD, so the larger the distance the lower the price, an opposite pattern in relation to US cities. Another interesting result is the negative sign of distance to a hospital. Meanwhile, the natural log of transport cost exhibited a positive relationship: housing price increased by just one percent when transportation costs increased by 10 per cent. The small change can be explained by the geography of the employment across the metropolis, with a pattern towards a polycentric structure.

The value of the coefficients show, in general, that quality was more important than size in determining housing prices in MCMA; quality was not related to materials used in the housing production, but rather to the additional equipment, such as a kitchen or a cistern. Neighborhood externalities, including access to running water and quality of elementary schools, were also important in determining housing prices. Higher housing prices were also related to proximity to the CBD (*dist_cbd*), so a house located at an average distance from CBD (15.88 kilometers) cost 12% less than those located in or around CBD. In comparing these results with those of other articles on urban economics, it seems that households in MCMA make a trade-off between accessibility and housing services (size and quality), constrained by their incomes, in the same way as households in developed cities. However, the main differences between these two groups is that housing prices in MCMA respond more to changes in the equipment and less to location. One explanation can be found

in the way the *dist_cbd* variable was measured (lineal distance from the municipal center to the *Zócalo*, instead of the actual distance between the house and *Zócalo*). Another explanation is related to the metropolitan structure, which shows a polycentric pattern, which implies the existence of distinct areas but with certain self-sufficiency among them in terms of their labor submarkets.

The estimated models 2, 3 and 4 show the results for different types of housing tenure. MCMA had 4.6 million dwellings in 2010; of them, 59% were owned by their inhabitants, 21% were rented and the remaining 20 percent were other types of tenure such as borrowed, intestate or some other situation. This distribution is very close to that obtained from the 2010 population and housing census. The three different kinds of housing tenure show, in general, the same pattern in explaining housing prices: quality is more important than size; running water is the main neighborhood externality; and there is a negative relationship with respect to distance to CBD. However, they did exhibit structural differences in some coefficient values: kitchen and cistern were more important in own houses with respect to dwellings on rent or other tenure; running water and lesser distance to CBD were more significant in rented houses.

According to Coulomb (2006), housing for rent in the MCMA includes six different types: *i*) old buildings (*vecindades*) in the center of the city; *ii*) old buildings in consolidated popular neighborhoods; *iii*) rooms for rent; *iv*) roof-top rooms; *v*) departments; and *vi*) houses. Rented housing was found to be more likely in households with an aging head of household, larger households, and single and divorced or separated people.

Structural differences were confirmed with a Chow test, because the null hypothesis (dependent variable follows the same model for own, rent and other tenure) was rejected at the 0.001 statistical significance level.⁴ Finally, model 5 shows the coefficients of the interaction terms of each independent variable with the variable *own*. As can be seen, housing prices for owner-occupied housing are more sensitive to house quality, and less to size, neighborhood attributes, and accessibility. In other words, prices on the rent housing market in Mexico City are mainly dominated by the size and location, while own housing market is driven by a preference for quality.

⁴ The values for the Chow test with only owned and rented houses were as follows: $SSR_R = 1013193$; $SSR_U = 959197$; $q = 16$; $n = 3645430$. The F was 12826, and the F_c is 1.64. As $F > F_c$ the null hypothesis is rejected, so there are significant differences in explaining housing prices between owned houses and dwellings that are rented.

4.1. Housing submarkets

Urban housing submarkets can be seen either as a cluster of dwellings which could represent close substitutes to each other, independently of where they are located, or as a cluster of dwellings with homogeneous prices, and price differentials with respect to other submarkets. Housing submarkets can be analyzed by using a prior delimitation, or they can be defined using a statistical tool, such as factor analysis, cluster analysis or spatial autocorrelation analysis. A multivariate statistical technique was chosen in this paper in order to explore the delimitation of submarkets in MCMA. The tool was the two-step, log-likelihood cluster analysis, using houses as observation units, and the 15 independent variables of the OLS hedonic model as attributes of these dwellings. The statistical exercise yielded five submarkets as seen in table 3.

Table 3
Statistics of housing submarkets

Variable	MCMA	Housing submarkets				
		Very high	High	Medium	Low	Very low
<i>N</i>	4 402	839	992	923	608	1 040
<i>N expanded</i>	4 575 449	841 671	1 072 174	973 588	633 238	1 054 778
<i>% of N expanded</i>	100.0	18.4	23.4	21.3	13.8	23.1
<i>Median price</i>	6 016	8 992	8 449	6 397	4 492	3 496
<i>Median income</i>	31 283	43 277	40 168	34 267	21 316	19 460
<i>Median housing units</i>	5.33	6.06	5.63	5.36	5.09	3.89

Source: prepared by the author by using data from INEGI (2012).

The results obtained from the housing submarkets appear to be consistent with the progression of control variables, such as median housing price, median income, and median housing units. Very high and high are close submarkets in terms of median housing price and median income, while the median incomes in the low and very low submarkets are close. Medium submarket is far from high and from low submarkets. There is also a progressive amount of the median

housing units, and it was from 3.9 housing units in the very low submarket, to 6.1 in the very high.

What does the term housing unit mean? Like any urban housing market, the housing stock in MCMA is a composite of physical characteristics, externalities and accessibility. It is not possible to measure or quantify a housing unit directly. The hedonic models for the MCMA that were estimated in this paper use an appropriate OLS function for establishing key variables to explain variations in the housing prices across the metropolis. Factor analysis was then used to reduce and summarize these variables into one indicator, called a *housing unit*.⁵ According to the results, the minimum housing unit in MCMA in 2010 was a dwelling located in the very low submarket, with one bedroom, six lights, no running water, located 50 kilometers from the CBD and close to primary schools with an average score in the *Enlace* test of 541. On the other extreme, the maximum housing unit was located in the very high submarket, with four bedrooms, 40 lights, running water, located 5 kilometers from the CBD, and close to primary schools, with an average score of 616.

The percentage distribution of dwellings by submarket was extended among the spatial units. On the one hand boroughs such as *Azcapotzalco*, *Xochimilco*, and the municipality of *Tultitlán*, showed a similar pattern to that of the MCMA as a whole. On the other hand there were boroughs and municipalities with a strong concentration in houses from only one submarket. Indeed in 18 municipalities, all their dwellings belonged to the very low submarket: *Tizayuca*, *Amecameca*, *Apaxco*, *Atenco*, *Cuautilán*, *Chicoloapan*, *Chiconcuac*, *Huehuetoca*, *Jilotzingo*, *Juchitepec*, *Nopaltepec*, *Ozumba*, *Tecámac*, *Temascalapa*, *Tepetlixpa*, *Tequixquiac*, *Villa del Carbón* and *Zumpango*.

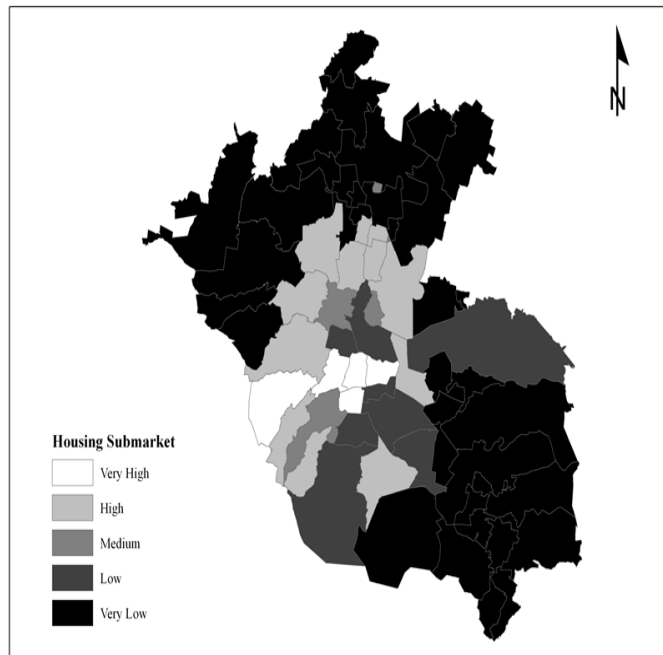
In order to spatialize urban submarkets, a correspondence analysis was applied. This instrument measures the association between two categorical variables, in this case spatial unit and housing submarket. The results of the exercise show that spatial units did not have a random distribution of dwellings by submarket, and that on average, dwellings from one submarket shared with around 70 per cent of the proportion of the cumulative inertia for each spatial unit (boroughs and municipalities). This indicates that correspondence

⁵ The Kaiser-Meyer-Olkin measure was 0.744; the factor explains 20% of the total variation; the most representative variables were *lights*, *water*, *educa*, *housing_growth* and *dist_cbd*. The lowest value was equalized to one in order to represent the minimum characteristics of a dwelling in the metropolitan housing market. It is clear that the low value of the explained variation of the factor could be a limitation for the analysis.

analysis is a useful tool for defining the metropolitan geography of housing submarkets in MCMA (map 1).

Dwellings in the very high submarket were concentrated in the four boroughs of the CBD (*Benito Juárez, Cuauhtémoc, Miguel Hidalgo* and *Venustiano Carranza*) and in the municipality of *Huixquilucan*. This can be seen by the fact that these neighborhoods accounted for 13% of the metropolitan housing stock but 40% of the very high dwellings in the metropolitan area. On the opposite end of the scale, 30 neighborhoods concentrated 16% of the housing of the metropolitan housing market, but 60% of the very low dwellings.

Map 1
Geography of housing submarkets



The spatial distribution of boroughs and municipalities, according to their main housing submarket, points to a center-periphery pattern. This arrangement confirms, on one hand, the decrease in

housing prices as their distance from the CBD increases, and on the other hand, the limited urban consolidation in the metropolitan periphery, due to the processes of self-build. However, it is important to mention that this lack of urban consolidation is not only an issue in the more peripheral municipalities, but also in an inner ring inside them. This means that urban consolidation is a long-term process.

A final finding refers to the structural differences in submarkets in terms of tenure of the dwelling. Very high and low submarkets are strongly connected to rent housing, while owned dwellings dominate the other three submarkets. Thus, the market for rented houses is located mainly in boroughs of the Federal District, and households living in homes they own are more representative in municipalities.

4.2. *Elasticities and residential mobility*

The housing unit measure was used to estimate demand elasticities (table 4). In this paper, the *demand income elasticity* is understood as the change in housing unit demanded, given a percentage change in the household income, and keeping the price constant. This elasticity was estimated at around 0.75 in US cities, and it means that an increase of 10% in the household income produces an increase of 7.5% in housing consumption (O'Sullivan 1996). Housing demand is inelastic to income, so consumption of other goods increases by a greater amount than does consumption of housing as income increases. On the other hand, the *demand price elasticity* is interpreted as the decrease in housing units demanded, given a percentage increase in price, keeping the income constant. Its value has been estimated at between -0.75 to -1.20 (O'Sullivan, 1996).⁶ An absolute value is less than one, indicates that it is an inferior good, and it is a superior good when absolute value is greater than one. However, in the case of inferior goods, the increase in price means a decrease in the consumption of other goods.

The elasticities for the MCMA housing demand as a whole were close to those of the US cities. In general, an increase of 10 per cent in the household income meant around seven per cent more in housing units demanded, that is, it is a normal good. On the other side, a 10 per cent increase in housing price meant around eight per cent less in

⁶ Demand elasticity of income was estimated with the model $Housing_unit = \alpha + \beta \ln income$; demand elasticity of price was produced with $Housing_unit = \alpha + \beta \ln price$.

consumption of housing units confirming that it is an inelastic good. The values of elasticities also showed that the substitution effect was higher than the income effect. In other words, with a high house price, households substitute that good for others relatively less expensive; conversely, a high household income produced more demand for housing. However, the absolute value of less consumption, based on the price, was higher than the absolute increase in demand due to changes in household's income. In other words, housing demand in MCMA is more sensitive to changes in prices in comparison to changes in income.

Table 4
*Demand elasticities by
housing submarket*

<i>Submarket</i>	<i>Income</i>	<i>Price</i>
Total	0.67	-0.78
High	0.38	-0.40
Medium high	0.34	-0.36
Medium	0.43	-0.44
Medium low	0.54	-0.67
Low	0.49	-0.60

Source: prepared by the author by using data from INEGI (2012).

However, differences in elasticities among housing submarkets in the MCMA market were different with respect to those for US cities, where the higher the household stratum the higher the elasticities. The very high submarket in the MCMA had both the lowest income and price elasticity, but it was the only submarket where the absolute value of income elasticity was higher than that of price elasticity. Meanwhile, the highest elasticities were in the low submarket. It seems that in the low submarket the households select a house as expensive as they could afford with the maximum expenditure they could make; this fits with the maximum housing expenditure theory Ellis (1967). On the opposite, the richest households are almost indifferent to changes in their housing prices as their incomes increase,

or as housing prices decrease, perhaps because they have their house already satisfies their utility functions, and no move is needed.

The trend in the demand income elasticity and demand price elasticity are key variables for explaining residential mobility. Households usually move because they expect to obtain better housing, in terms of the dwelling size, quality, and neighborhood attributes (Cooper, Ryley and Smith, 2001; Pacione, 2001; Wang and Li, 2004); because of a change in the workplace (Gayda, 1998; Kim, Pagliara and Preston, 2005), or due to changes in the household's life course (Chang, Chen and Somerville, 2003; Earnhart, 2002).

In the US metropolitan areas, there were 238.1 million people over five years old in 2010, and from them, 61.3 million moved within the same metropolitan area between 2005 and 2010 (five years metropolitan mobility). This means a mobility rate of 51 people per one thousand inhabitants per year.⁷ In the case of Mexico, for the same year there were 59 metropolitan areas (SEDESOL, CONAPO and INEGI, 2012) with a total population of 63.8 million people, and the rate of metropolitan mobility between 2005 and 2010 reached 2.4 million people. The mobility rate was 8 people per one thousand inhabitants per year; it means that in the US the metropolitan mobility was six times higher.

In the MCMA, the population that moved from one borough or municipality to another within the metropolitan area between 2005 and 2010 was 1.3 million people, which represented a rate of 13 people per one thousand inhabitants per year.⁸ The lower mobility within Mexican metropolitan areas, and specially within the MCMA, can be explained as follows: first, housing prices have grown much faster than household incomes; second, housing prices affect low residential mobility, except for the very high submarket; and third, increasing housing prices lead to a greater residential mobility towards lower-hierarchy submarkets. These explanations are discussed in the next paragraph.

According to the SHF, the price index of housing in the Federal District grew from 76.8 in 2005 to 120.0 in 2012, while in the state of Mexico, this index increased from 78.2 to 114.7. This implies an average annual rate of growth of 6.6% in the Federal District and 5.6% in the state of Mexico (SHF, 2013b). On the other hand, the increase

⁷ http://www.census.gov/hhes/migration/data/cps/cps2010-5yr.ht/table_16

⁸ Metropolitan mobility for the Mexican metropolitan areas, and for the MCMA were calculated by using micro data from the 2010 national census of population and housing.

in the minimum wage was only 4.2% per year for the same time period. Indeed, a very low proportion of the working population receives the minimum wage, but salaries in the formal and modern sector have tended to converge with those in the traditional and informal sector (Puyana and Romero, 2012).

The income effect was greater than the substitution effect in the very high submarket, so spatial units that constitute this submarket had the highest mobility rates, with a value of 17 persons per one thousand inhabitants per year. On the other hand, spatial units in the very low submarket had also high residential mobility. In summary, of all the metropolitan residential movements that occurred between 2005 and 2010, 27% were upward (from a lower-level borough or municipality of housing submarket to a higher level), 28% were between spatial units in the same submarket, and 45% were downward (from a higher to a lower-level spatial unit). The predominance of movements towards a lower submarket, could signify a gentrification process, in opposition to the results of Sánchez (2012), who showed evidence of the consolidation of a segregation pattern during the 1990-2005 period. In other words, this segregation might have begun to reverse during the second half of the new millennium's first decade due to changes in housing prices.

5. Final Remarks

The spatial structure of the MCMA is complex and heterogeneous. Its 20 million inhabitants are distributed in different geographical and social stratification areas, and in different housing submarkets. In this paper, hedonic housing price models were estimated to find the key variables in explaining metropolitan housing, to explore the delimitation of geographical submarkets, and to prove some theoretical postulates about the functioning of the MCMA housing market. We can conclude the following: *i*) MCMA has a housing market divided into geographical submarkets; *ii*) the housing price is determined by a mix of physical characteristics of the dwelling, neighborhood externalities, and accessibility; *iii*) the key variables determining the variation in housing prices are similar to those found in the theoretical literature and in the evidence from US cities, although the physical characteristics of owner-occupied houses, were more important in explaining housing price in MCMA, while externalities and location were more important in determining rented housing; *iv*) the general spatial structure shows a decreasing pattern in the housing

price as distance from the CBD increases; *v*) the intensity of residential mobility is higher among the very high and the very low housing submarkets; *vi*) the substitution effect was more important than the income effect in the dynamics of the housing market, except for the very high submarket; and *vii*) the rational choice of the households in demanding a house includes a trade-off between physical characteristics of the dwelling (and neighborhood attributes), and distance to the workplace, because the higher the income the higher the transport costs. All these elements should be taken into account for public policy formulation and implementation in this megacity.

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